Received: 10 September 2024 | Revised: 23 October 2024 | Accepted: 23 October 2024

DOI: 10.1111/iwj.70137

ORIGINAL ARTICLE

IWJ WILEY

Comprehensive cost-of-illness analysis of pressure ulcer treatment: A real-world study at a Czech university hospital

Lenka Krupová[1] | **Andrea Pokorná**[2,3] | **Miroslav Krupa**[4] | **Klára Benešová**[3]

[1]Department of Dermatology, University Hospital Ostrava, Ostrava, Czech Republic

[2]Department of Health Sciences, Faculty of Medicine, Masaryk University, Brno, Czech Republic

[3]Institute of Biostatistics and Analyses, Faculty of Medicine, Masaryk University, Brno, Czech Republic

[4]Faculty of Business Administration, Prague University of Economics and Business, Prague, Czech Republic

Correspondence
Andrea Pokorná, Department of Health Sciences, Faculty of Medicine, Masaryk University, Kamenice 753/5, 625 00 Brno, Czech Republic.
Email: apokorna@med.muni.cz

Funding information
Ministerstvo Zdravotnictví Ceské Republiky, Grant/Award Number: NU20-09-00094

Abstract

Pressure ulcers (PUs) impose a significant economic burden on healthcare systems, affecting patient quality of life and leading to substantial treatment costs. This study presents a cost-of-illness analysis of PU treatment in hospitalized patients in the Czech Republic, based on real-world clinical data. The analysis was conducted using a comprehensive methodology at a Czech university hospital, involving 304 hospitalizations. The study included all hospitalized patients with PUs. Data were collected employing a bottom-up, person-based approach, which refers to the collection and analysis of cost data at the individual patient level. This method captures detailed resource utilization for each patient. The methodology accounted for both systemic and local costs, including materials, medications, caregiver time, and procedures. The study involved 304 hospitalizations, with a mean length of stay of 13 days. The total cost of PU treatment, excluding pharmacotherapy, had a median of €678, while including pharmacotherapy, the median cost rose to €929. Younger patients incurred higher treatment costs. Significant cost variations were observed among different departments. We developed and applied a novel cost model to quantify the expenses associated with PUs, which accurately highlighted the financial burden in the hospital care setting. We present a rigorous methodology for PU cost-of-illness analysis, providing a valuable tool for future research and clinical practice. This comprehensive approach supports the development of targeted interventions to reduce the incidence and severity of PUs, ultimately improving patient care and reducing healthcare costs.

KEYWORDS

cost analysis, healthcare costs, patients, pressure ulcers, treatment costs

Key Messages

- Accurate cost-of-illness analysis of pressure ulcer treatment is crucial for improving patient outcomes and reducing healthcare costs.
- This study developed a methodology to calculate PU treatment costs, using data from 304 hospitalizations at a Czech university hospital.
- The median PU treatment cost was €678 (excluding pharmacotherapy) and €929 (including pharmacotherapy), with significant cost variations across departments.
- The cost model provides a tool for targeting interventions in pressure ulcers' management to reduce financial burden and enhance patient care.

1 | INTRODUCTION

Pressure ulcers (PUs) are localized damages to the skin and underlying tissue caused by sustained pressure, often exacerbated by shear forces.[1] These injuries affect a substantial number of individuals,[2,3] incurring significant healthcare costs and severely diminishing the quality of life.[4] Notably, not all PUs are avoidable, particularly in critically ill patients where preventive measures may be impractical or contraindicated.[5]

The financial burden of PUs is considerable, especially in the context of constrained healthcare resources. Higher-category PUs are particularly costly, with expenses often surpassing previous estimates.[6] Furthermore, recent studies suggest that the incidence of PUs might be underreported.[7,8] Hence, accurately identifying the costs associated with PU prevention and treatment and understanding their broader impacts is essential.[9]

Preventing or halting the progression of early-stage PUs can alleviate pain and suffering, save lives, and reduce healthcare costs. Previous studies, including our pilot study,[10] have underscored the complexities and significant expenses involved in PU management, highlighting the necessity for a detailed and standardized approach to cost analysis. Our methodology builds on this prior work by incorporating patient-specific data on direct medical costs, indirect costs, and non-medical expenses, thus providing a more precise and comprehensive analysis of PU-related costs.

This study provides novel insights by developing a comprehensive methodology for PU cost analysis, including a cost-of-illness model based on real-world clinical data from the Czech Republic. This approach aligns with international standards and offers applicability beyond the local healthcare system. By providing a detailed and potentially standardized method for quantifying the costs of PU treatment, the study fills an important gap in existing cost analyses.

Unlike previous studies, this model focuses on real-world patient-level data, capturing detailed cost elements such as materials, medications, and caregiver time. Through a comprehensive cost monitoring process, we aim to enhance the accuracy of economic evaluations and facilitate more effective resource allocation in healthcare settings. Our ultimate goal is to provide healthcare providers with a reliable tool for economically evaluating PU treatment, thereby supporting informed decision-making and policy development.

2 | METHODS

This study follows the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) 2022 guidelines[11] to ensure that the development and reporting of the cost-of-illness model are comprehensive, transparent, and aligned with international standards for health economic evaluations. By adhering to these guidelines, we ensure that all relevant aspects of the model development, including cost data collection, analysis, and presentation, are reported with clarity and accuracy.

2.1 | Study design

This study employs a cost-of-illness design based on real-world data to analyse the economic burden associated with PU treatment in hospitalized patients. This economic evaluation is conducted from the hospital care perspective, focusing on the costs incurred during the hospitalization of patients with PUs. The research was conducted at the university hospital, encompassing the Clinic of Anesthesiology Resuscitation and Intensive Medicine (CARIM), the Internal Clinic, and the Surgical Clinic. These clinics were selected for efficiency in data collection, as history records from the hospital information system (HIS) indicate that most PUs occur in these three clinics. The study period was divided into two parts: a pilot phase from March to May 2022, followed by the main study phase from February to July 2023. The pilot

successfully validated the data collection process, with minor adjustments made to improve the user experience for entering data. Therefore, data from the pilot were included in the final analysis. The time horizon for this cost-of-illness analysis was limited to the duration of the patient's hospitalization, as the study aimed to capture all costs incurred during the patient's stay for PU treatment. All hospitalized patients with PUs were included in the analysis during both phases.

2.2 | Participants

All patients hospitalized with PUs during the study period were included in the analysis. All categories of PU according to the international NPUAP/EPUAP system of PU classification were included.[12] Inclusion criteria required the presence of at least one PU. The exclusion criteria included incomplete data, defined as cases where our consistency checks revealed that not all days of hospital stay with a PU were documented in the HIS. Extreme outliers were hospitalizations with unusually long durations (42, 89, and 117 days), which could distort the overall cost model, or missing critical data that would significantly impact the cost analysis.

2.3 | Data structure

A structure for data collection was developed based on the umbrella review,[13] consultations with foreign experts on cost-effectiveness, and the research team's experience from practice.

The cost analysis was structured to include both systemic and local costs associated with PU treatment. Systemic costs refer to expenses incurred regardless of the number of PUs a patient has, such as general hospital stay costs and basic nursing care. Local costs are specific to treating each individual PU, including specialized dressings, topical treatments, and wound care consultations.

The detailed cost components recorded for each patient encompassed a variety of elements. These included materials such as passive and active mattresses, positioning aids, and wound care supplies. Pharmacotherapy, which includes antibiotics and analgesics (painkillers), is included under systemic costs. As it is not possible to distinguish whether these medications are exclusively related to PU treatment, they are considered part of the overall systemic costs. The costs of medical procedures, such as blood tests, histology, microbiology, x-rays, surgical necrectomy, debridement, and negative pressure wound therapy (NPWT) application, were meticulously documented. Additionally, the time caregivers, including nurses, physicians, and other specialists (consultations of physiotherapists, nutritionists, etc.), spent on PU prevention and treatment was recorded. Nutritional support costs covered products and their administration. Personal protective equipment (PPE) costs included gloves, gowns, masks, and other protective gear. PPE costs were included because they were specifically used during interventions related to PU treatment. These costs are directly connected to wound care procedures, such as dressing changes or wound monitoring, and thus quantify the costs of protecting the health of caregivers and preventing further complications, including transmission of infection closely related to wound management. Finally, expenses related to medical and municipal waste disposal were included. Items that would have been paid for by the patients themselves to manage PUs outside of public health insurance were not included. Also, to ensure that these items did not affect the costing model, the study was conducted on hospitalized patients. A comprehensive table detailing these cost components is provided in Table 1.

2.4 | Data collection

Data collection was conducted using the HIS, which integrates both outpatient and inpatient electronic medical and nursing records. To ensure consistency and accuracy, data entry was performed using electronic forms specifically designed for this study and integrated into the HIS as an extension of the nursing electronic documentation. Each ward had an assigned wound healing consultant, who received prior methodological training to facilitate this process as a data manager for the study. Unlike standard medical documentation, these forms were customized to capture detailed information on PU treatment. The data entry process involved two screens: one for tracking the use of mattresses and positioning aids, noting start and end dates to calculate total usage days, and another for documenting the time and materials used during each 12-h shift. Time was recorded in minutes, while materials were logged in appropriate units such as pieces, millilitres, centimetres, and squirts.

Despite our reliance on the umbrella review results and CHEERS reporting guidelines, designing the methodology for data collection and subsequent cost quantification presented numerous challenges. One significant issue was the variety of product forms, such as solutions, sprays, and ointments, and the difficulty in accurately recording their consumption per patient since these products are often used for multiple patients. To address this, we implemented specific measures for precise documentation.[10]

TABLE 1 Cost structure and sources of unit costs.

Cost category	Cost component	Source of unit cost
Pressure relief aids (cost per aid)	Passive mattress (S) Active mattress (S) Positioning aids (S)	Hospital warehouse for medical equipment and supplies
Procedures performed (cost per examination/ procedure)	Blood test—C-reactive protein (S) Blood test—complete blood count (S) Blood test—proteins (S) Histology collection (L) Microbiology (wound swab) (L) X-ray examination (S) Surgical necrectomy (physician) (L) Debridement (autolytical) (L) NPWT application (L)	List of medical procedures
Dressings and medical products (cost per unit of amorfous material—mL and area of coverage/ dressing – cm)	Prevention (S) Wound irrigation solution (L) Periwound skin management (L) Primary dressing (L) Secondary dressing (L)	Hospital warehouse for medical equipment and supplies
Medications (cost per dose of the drug)	Antibiotics (S) Analgesics (S)	Hospital pharmacy
Personal protective equipment—PPE (cost per piece)	Gloves (S) Gown (S) Protective glasses (S) Face mask (FFP2 Respirator) (S) Shield (S) Overshoes (S)	Hospital material warehouse
Time devoted to multidisciplinary care (cost per minute)	Prevention of PUs (S) Patient positioning (S) PUs treatment (L) Other nursing care and interventions related to PUs (e.g., peri-wound skin care, education) (L) Consultation with the attending physician (S) Consultation with a surgeon (S) Consultation with a dietitian (S) Nutritional therapist consultation (S) Treatment/care of a physiotherapist (S) Consultation with a wound healing specialist (L) Consultation with another specialist (S)	Hospital payroll office (average rates)
Material equipment (cost per piece, cost per unit of amorphous material—mL)	Washing wipes (L) Disinfectant wipes (L) Wound pads (L) Emission trays (L) Hand disinfectant (S) Use of special incontinence aids – disposable pads (S) Use of special incontinence devices—nappies Flexi-Seal (S) Permanent urinary catheter (S)	Hospital warehouse for medical equipment and supplies
Nutritional support (cost per dose of product)	Nutritional support—sipping (S) Nutritional support product—i.v. application (S) Enteral nutrition (S)	Hospital pharmacy

TABLE 1 (Continued)

Cost category	Cost component	Source of unit cost
Waste disposal (cost per kg of waste)	Medical (S) Municipal (S)	Hospital Department of the Deputy Director for Technology and Operations

Note: Material counted as—(S) systemic costs, (L) local costs.

For sprays, we recorded the number of squirts, having experimentally determined that 10 squirts equate to 1 mL for several products. For creams, we measured the squeezed content in centimetres, using a conversion rate of 5 cm to 1 g. This approach ensured accurate tracking of usage. To calculate costs, we derived the unit price from the product price and its volume or weight and then multiplied this unit price by the recorded quantity. A similar procedure was adopted for solutions and nutritional products, ensuring comprehensive and precise cost quantification. This approach enabled us to achieve maximum material pricing accuracy, enhancing our cost analysis's reliability.

While the analysis used prices in Czech crowns (CZK), all costs were converted to euros (EUR) for this article, with rounding to whole Euros for all reported amounts. The conversion rate was calculated as the arithmetic mean of monthly averages from March to May 2022 and February to July 2023, sourced from the Czech National Bank, resulting in an average EUR to CZK rate of 24.0253.

In addition to collecting data specific to PUs, the methodology included the assessment of common nursing scales that are part of standard medical documentation. These scales covered various aspects such as pain levels (VAS—visual analogue scale), patient dependency (Barthel test—activity of daily living test), Norton score, nutritional status, and other relevant factors. This comprehensive data collection approach allows for a more detailed analysis of the patient condition and care requirements, which are later discussed in the context of their impact on the costs and outcomes of PU treatment.

2.5 | Data analysis

The data were extracted from the HIS database using structured query language (SQL) and processed using Microsoft Excel. Statistical analysis was performed using IBM SPSS Statistics at a significance level of 0.05, employing the Mann–Whitney U test for comparing two groups, the Kruskal–Wallis test for multiple group comparisons, and linear regression for modelling cost estimates. To characterize the uncertainty in the cost estimates, confidence intervals were calculated for the regression coefficients in the cost model.

The total quantity was determined for each cost item based on the specific records and evidence for the items analysed (see Table 1). This quantity was then multiplied by the corresponding unit price, with the sources for these unit prices also detailed in Table 1. Subsequently, the costs for each item were summed up by cost category, both in total and as daily averages.

We developed a novel cost model to estimate the costs of treating hospitalized patients with PUs. The model differentiates between systemic (S) and local costs (L) and uses linear regression to calculate costs based on various parameters, including the most severe PU category, total days with PU, and the number of PUs per patient. The model's coefficients were estimated using linear regression without a constant, allowing for a detailed breakdown of both systemic and local costs.

2.6 | Validation and reliability

The methodology was validated through internal audits and consultations with foreign experts on cost-effectiveness. Pilot data were used to refine the cost components and ensure the robustness of the calculation model. Outliers and incomplete records were excluded to maintain data quality.

3 | RESULTS

A total of 308 hospitalizations were initially documented during the pilot phase from March to May 2022, followed by the main study phase from February to July 2023. After excluding four hospitalizations due to extreme values and missing data, 304 were included in the final analysis. Detailed characteristics of the sample, including age, gender, length of stay, and department distribution, are provided in Table 2. The sample predominantly consisted of older adults (average age 72 years), with balanced gender distribution and varying hospitalization durations across departments.

TABLE 2 Basic characteristics of patients.

Parameter	Category	Value
Gender	Male	152 (50.0%)
	Female	152 (50.0%)
Age	Total	72 ± 15
	<50 years	30 (9.9%)
	50–64 years	45 (14.8%)
	65–79 years	123 (40.5%)
	80+ years	106 (34.9%)
Clinic	Surgical Clinic	50 (16.4%)
	Internal Clinic	176 (57.9%)
	CARIM	78 (25.7%)
Length of hospitalization	Total	13 ± 9
	Surgical Clinic	12 ± 10
	Internal Clinic	12 ± 9
	CARIM	14 ± 10
Length of hospitalization with PU	Total	9 ± 8
	Surgical Clinic	9 ± 9
	Internal Clinic	9 ± 7
	CARIM	10 ± 8
Number of PUs per patient	1	196 (64.5%)
	2	71 (23.4%)
	3	21 (6.9%)
	4 and more	16 (5.3%)
Most severe PU category	1	51 (16.8%)
	2	155 (51.0%)
	3	47 (15.5%)
	4	19 (6.3%)
	Unstageable or deep tissue injury	32 (10.5%)
BMI	Total	27 ± 7
	<18.5, underweight	19 (6.3%)
	18.5–25, normal weight	105 (34.5%)
	25–30, overweight	61 (20.1%)
	>30, obesity	81 (26.6%)
	Not specified	38 (12.5%)
ADL score	0	11 (3.6%)
	2	84 (27.6%)
	3	179 (58.9%)
	Not specified	30 (9.9%)
Norton score	Total	19 ± 5
	<16	90 (29.6%)
	16–20	103 (33.9%)
	>20	110 (36.2%)
	Not specified	1 (0.3%)

TABLE 2 (Continued)

Parameter	Category	Value
Primary hospitalization diagnose (chapters ICD-10)	I. Certain infectious and parasitic diseases	42 (13.8%)
	II. Neoplasms	12 (3.9%)
	III. Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	9 (3.0%)
	IV. Endocrine, nutritional, and metabolic diseases	20 (6.6%)
	V. Mental and behavioural disorders	3 (1.0%)
	VI. Diseases of the nervous system	3 (1.0%)
	IX. Diseases of the circulatory system	40 (13.2%)
	X. Diseases of the respiratory system	52 (17.1%)
	XI. Diseases of the digestive system	32 (10.5%)
	XII. Diseases of the skin and subcutaneous tissue	11 (3.6%)
	XIII. Diseases of the musculoskeletal system and connective tissue	5 (1.6%)
	XIV. Diseases of the genitourinary system	40 (13.2%)
	XVIII. Symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified	4 (1.3%)
	XIX. Injury, poisoning, and certain other consequences of external causes	25 (8.2%)
	XXI. Factors influencing health status and contact with health services	1 (0.3%)
	XXII. Codes for special purposes	5 (1.6%)
The most frequent diagnoses (≥E10 cases)	A41 Other sepsis	24 (7.9%)
	N39 Other disorders of urinary system	22 (7.2%)
	J18 Pneumonia, organism unspecified	16 (5.3%)
	I70 Atherosclerosis	14 (4.6%)
	T06 Other injuries involving multiple body regions, not elsewhere classified	10 (3.3%)

Note: For categorical parameters, the absolute and relative numbers are given; for continuous parameters, the mean and standard deviation are provided.
Abbreviations: ADL, activity of daily living; BMI, body mass index.

The data on the number of PUs per patient shows that most patients (64.5%) had a single PU, but a significant minority (35.5%) had multiple PUs, highlighting the need for specialized care in these cases. The severity of the most severe PU indicates that more than half of the patients (51.0%) had Category 2 ulcers, which require considerable medical attention, while a smaller percentage had more severe ulcers.

Analysing departmental distribution, the majority of patients (57.9%) were from the Internal Clinic, which may reflect the nature of PUs being more prevalent in patients with chronic medical conditions (polymorbid patients). The average body mass index (BMI) of 27, with a notable proportion of patients classified as overweight or obese (46.7%), underscores the importance of addressing weight management in the prevention and treatment of PUs.

The activity of daily living (ADL) scores reveal that a large majority of patients (58.9%) required significant assistance with daily activities, indicating a high level of dependency. The Norton scores further support this, with nearly one-third of the patients (29.6%) at high risk for developing PUs, emphasizing the need for preventive measures in this vulnerable group.

The primary hospitalization diagnoses, categorized by ICD-10 chapters, show a diverse range of underlying health issues, with the most common being diseases of the respiratory system, circulatory system, and infectious diseases. This variety in primary diagnoses suggests that PUs are a widespread issue across different medical conditions. Notably, certain diagnoses, such as other sepsis (A41) and other diseases of the urinary system (N39), were among the most frequent specific conditions.

In Tables 3 and 4, we present a detailed breakdown of the total costs associated with PU treatment, categorized by patient characteristics such as gender, age, the severity of the most severe (highest category) PU, clinic, BMI, ADL score, and Norton score. Table 3 focuses on costs excluding pharmacotherapy, while Table 4 includes pharmacotherapy costs, providing a comprehensive view of the financial burden across different patient demographics and clinical settings. Additionally, these tables include p-values for statistical tests, evaluating whether

TABLE 3 Total costs in EUR (excluding pharmacotherapy) by patient characteristics.

Parameter	Category	Median (EUR)	IQR (EUR)	*p*-value
Total	-	678	295–1261	-
Gender	Male	746	291–1261	0.553
	Female	577	295–1248	
Age	<50 years	1026	477–1772	0.037
	50–64 years	739	490–1268	
	65–79 years	763	303–1397	
	80+ years	553	261–936	
The most severe PU category	1	496	226–1004	0.118
	2	604	300–1183	
	3	780	280–1560	
	4	1054	526–1823	
	Unspecified	804	340–1558	
Clinic	Surgical Clinic	369	111–800	<0.001
	Internal Clinic	712	330–1093	
	CARIM	1098	387–1772	
BMI	<18.5, underweight	500	333–800	0.422
	18.5–25, normal weight	756	255–1384	
	25–30, overweight	604	300–1486	
	>30, obesity	822	323–1424	
ADL Score	0	746	226–1564	0.166
	2	560	211–1054	
	3	766	302–1331	
Norton Score	<16	773	348–1486	0.107
	16–20	746	291–1411	
	>20	561	212–1069	

Note: The *p*-value of the Mann–Whitney U test is presented. For comparisons involving more than two categories, the *p*-value of the Kruskal–Wallis test is provided.

Abbreviations: ADL, activity of daily living; BMI, body mass index.

there are statistically significant differences among the various categories of characteristics.

The median total cost for the cohort, excluding pharmacotherapy, was €678 (IQR: €295–€1261). Cost analysis by gender showed no significant difference ($p = 0.553$), with males incurring slightly higher median costs (€746) compared to females (€577).

Age had a significant impact on costs ($p = 0.037$). Patients younger than 50 years incurred the highest median costs (€1026), while those aged 80 and above had the lowest (€608).

The primary cost contributors for PU treatment were antibiotics (40.3% of total costs), time devoted to multidisciplinary care (32%), and material equipment (13.4%). When comparing costs by the severity of the most severe PU (the highest PU category), no statistically significant differences were found ($p = 0.118$). However, a trend was observed where costs increased with the severity of the ulcer, with Category 4 ulcers having the highest median cost (€1068). Higher costs were driven primarily by surgical procedures (e.g., debridement, surgical necrectomy), increased time devoted to multidisciplinary care, and the use of specialized material equipment like NPWT. These cost drivers contributed significantly to the increased median cost as PU severity increased.

It is important to note that Tables 3 and 4 provide only a very rough statistical assessment. For instance, factors such as the number of PUs a patient has, their specific categories, and the length of hospitalization are not adjusted for in this analysis. This simplification serves to describe which patient groups are generally the most expensive without delving into finer details. A better fit for understanding cost variations is provided by a linear regression model, which is described further in the results section.

TABLE 4 Total costs in EUR (including pharmacotherapy) by patient characteristics.

Parameter	Category	Median (EUR)	IQR (EUR)	*p*-value
Total	-	929	436–1947	-
Gender	Male	1013	433–2268	0.176
	Female	798	440–1864	
Age	<50 years	2624	821–5303	<0.001
	50–64 years	1066	609–2192	
	65–79 years	692	356–1148	
	80+ years	608	393–1414	
The most severe PU category	1	943	426–1947	0.340
	2	951	534–2288	
	3	1087	573–2004	
	4	1068	481–2761	
	Unspecified	692	356–1148	
Clinic	Surgical Clinic	608	288–1211	<0.001
	Internal Clinic	810	423–1398	
	CARIM	2171	911–4972	
BMI	<18.5, underweight	743	426–1068	0.392
	18.5–25, normal weight	1039	415–2054	
	25–30, overweight	935	440–2109	
	>30, obesity	1051	529–2709	
ADL score	0	755	262–3977	0.806
	2	763	448–1488	
	3	935	415–1907	
Norton score	<16	1034	587–2688	0.174
	16–20	935	356–2054	
	>20	842	415–1613	

Note: The *p*-value of the Mann–Whitney U test is presented. For comparisons involving more than two categories, the *p*-value of the Kruskal–Wallis test is provided.
Abbreviations: ADL, activity of daily living; BMI, body mass index.

Significant differences were observed across different departments ($p < 0.001$). Patients treated in the CARIM department incurred the highest median costs (€1098), reflecting the intensive care required. In contrast, the patients from Surgical Clinic had the lowest median costs (€369).

BMI categories did not show a significant impact on costs ($p = 0.422$). However, patients with obesity (>30 BMI) had higher median costs (€822) compared to those with underweight or normal weight.

ADL scores also did not significantly affect costs ($p = 0.166$). Patients with an ADL score of 3 had slightly higher costs (€766) compared to those with lower scores.

Norton scores did not show a significant relationship with costs ($p = 0.107$). Patients with scores less than 16 had slightly higher costs (€773).

The inclusion of pharmacotherapy increased the median total costs to €930 (IQR: €436–€1947). Gender differences in costs remained statistically insignificant ($p = 0.176$), with males incurring higher costs (€1014) than females (€798).

Based on the data, a calculation model was developed to estimate the cost of treating a hospitalized patient with PU. For the purpose of the analysis, we divided each cost item into systemic (S), which applies to the patient regardless of the number of PUs, and local (L), which applies to a specific PU, as outlined in the methodology.

The coefficients of the calculation formula (see Table 5) were estimated using linear regression without a constant.

$$C = d \times \beta_{SX} + \sum_{i=1}^{n} d_i \times \beta_{LY_i},$$

where C, total cost of PU treatment; X, the most severe PU category for a given hospitalization; d, total days with PU (of any category); d_i, total days with PU of category i;

Local	β_{L1} [EUR]	β_{L2}[EUR]	β_{L3} [EUR]	β_{L4} [EUR]	β_{L5} [EUR]
	8.20	6.99	6.58	13.73	11.24
95% CI	5.91–10.53	5.79–8.15	4.83–8.29	10.41–17.08	8.21–14.29
Systemic	β_{S1} (EUR)	β_{S2} (EUR)	β_{S3} (EUR)	β_{S4} (EUR)	β_{S5} (EUR)
Without pharmacotherapy	77.08	82.36	86.59	87.28	84.47
95% CI	66.63–87.53	76.34–88.30	75.73–97.49	70.16–104.26	71.31–97.67
With pharmacotherapy	135.78	197.75	181.74	116.06	229.49
95% CI	68.42–203.14	159.17–236.32	111.56–251.92	4.85–226.03	144.70–314.28

Abbreviation: CI, confidence interval.

TABLE 5 Coefficients for calculation of the cost of PUs treatment during hospitalization.

n, number of PUs in a given hospitalization; Y_i, category of i-th PU ($i = 1, \ldots n$); β_{SX}, linear regression coefficient for systemic costs for PU of category X ($X = 5$ for unstageable or deep tissue injury); β_{LYi}, linear regression coefficient for local costs for PU of category Y_i ($Y_i = 5$ for unstageable or deep tissue injury).

For example, if we have a patient hospitalized for 8 days with a Category 3 PU, and during the hospitalization, another Category 1 PU has developed after 5 days. Therefore, the number of days with any PU is 8. The number of days with Category 3 PU is 8, and the number of days with Category 1 PU is 3. The cost without pharmacotherapy then will be:

$$C = 8 \times \beta_{S3} + 8 \times \beta_{L3} + 3 \times \beta_{L2}$$
$$= 8 \times €86.59 + 8 \times €6.58 + 3 \times €8.20 = €769.96.$$

Figure 1 shows a comparison of calculated costs with actual costs.

4 | DISCUSSION

Our study, similar to most research on the costs of preventing or treating PUs,[9] adopts a bottom-up, person-based approach. Unlike many other studies, we accurately quantified most cost items based on actual records for each patient. This approach not only facilitated a more precise cost analysis but also allowed for comparisons between different clinics where the study was conducted. It also provided a foundation for improving treatment procedures and acted as an internal audit of adherence to recommended PU treatments at the university hospital. However, this method required addressing several practical challenges related to recording the time spent, medications, dressings, consumables, etc., to ensure accurate data collection within the busy operations of the participating departments and staff. In contrast, other studies often estimate a significant portion of items or entire cost categories using average consumption by approximating based on limited parameters or even by adopting data from other studies.[14] Consequently, we had to develop much of the data collection methodology and subsequent costing procedures ourselves.[10] These variations make comparisons of aggregated results across different studies indicative rather than definitive.

Regarding the cost structure and calculation, there is no standardized approach.[9,13] Each study tends to follow its own methodology. However, there is a general agreement on basic cost categories such as dressings, rinses and ointments, antibiotics and analgesics, caregivers' time, debridement, and positioning aids.[6,15] For other cost categories and their subdivisions, methodologies vary or are often not detailed in most articles. The way these costs are quantified also differs significantly. We faced challenges in accurately costing items for both systemic and local therapies, particularly with the costs of liquids, amorphous agents, and positioning aids. When comparing studies from different years, factors like discounting and local economic conditions, such as labour costs, which can differ substantially, must be considered. Despite these challenges, our results are broadly comparable to other studies in similar contexts.[16,17]

The cost analysis reveals several important insights. Younger patients incur higher treatment costs, potentially due to more aggressive or advanced treatments required. While older age is often linked to delayed wound healing and an increased risk of PU occurrence,[18] younger patients are identified as having a higher risk for PU recurrence following surgical reconstruction.[19]

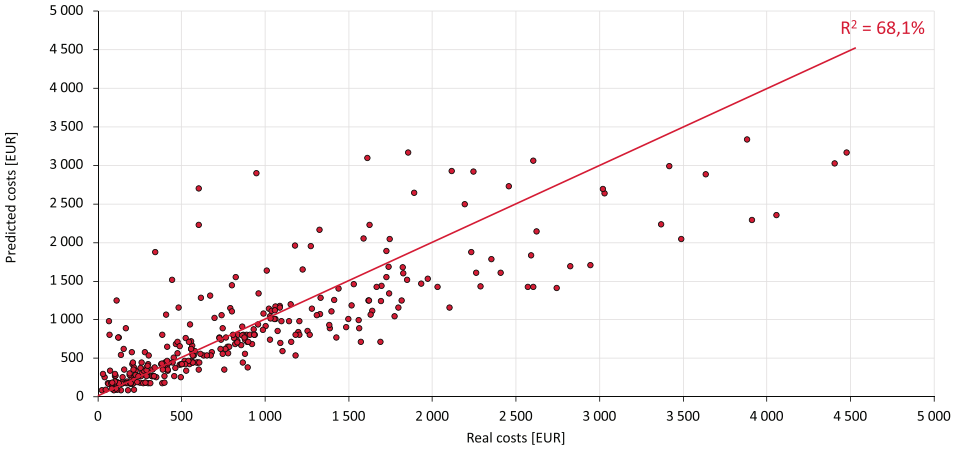

FIGURE 1 Comparison of real and projected costs without pharmacotherapy. More extensive data is available and can be obtained from the main author upon reasonable request.

Additionally, our finding that significant cost variations across different departments suggest the type of care setting plays a critical role in overall expenses, with intensive care settings like CARIM being particularly costly, is also confirmed by other studies, including Cooper.[20]

The relationship between BMI and costs, while not statistically significant, points towards higher costs associated with obesity,[21] likely due to complications and additional care needs. ADL and Norton scores, although not showing a strong statistical relationship with costs, still highlight trends where higher dependency and lower scores correlate with increased financial burdens.

The inclusion of pharmacotherapy in cost analysis presents additional complexity. Identifying the portion of pharmacotherapy costs directly attributable to PU treatment versus other diagnoses is challenging, particularly in intensive care unit settings where patients often present with multiple, serious conditions. For instance, antibiotics and analgesics, which contribute significantly to pharmacotherapy costs, might be used to treat underlying infections or other complications unrelated to PUs, thereby inflating the perceived costs associated with PU management.

Additionally, because we can only track entire packages in the HIS and not the portion of the package consumed, long hospitalizations may appear cheaper as the cost of antibiotics is distributed over more days. However, this does not significantly impact the statistical correlation, as the Spearman correlation coefficient is 0.050, with a p-value of 0.384, indicating statistical insignificance between the length of stay and average daily costs.

These findings underscore the complexity of managing PUs in hospitalized patients, emphasizing the need for targeted interventions and resource allocation to manage costs effectively. The impact of pharmacotherapy on total costs further highlights the necessity of considering medication costs in overall financial planning for patient care.

The sample included nearly equal numbers of men and women, with women being, on average, approximately 10 years older than men. This aligns with the fact that women in the Czech Republic tend to live longer and are, therefore, at a higher risk of developing chronic wounds, including PUs. This finding is also partially supported by a recent study by Lichterfeld-Kottner et al.[22] Moreover, PUs are more typical among the elderly population, further highlighting the vulnerability of older adults to such conditions.[18]

Based on the findings of this study, a national methodology for cost analysis of PU treatment was developed. This methodology focuses on identifying key cost items, including basic patient identification data, the structure of preventive and therapeutic measures, material equipment, diagnostic methods, surgical procedures, overall medication, and consumables.

It employs a 'bottom-up' approach, allowing for precise cost analysis by quantifying real-world data. This methodology is currently in the formal approval process by the Ministry of Health of the Czech Republic, with preliminary indications suggesting a positive outcome. Special attention was paid in the methodology not only to the listing of individual parameters but also to their description for inclusion in analyses and availability in health record data sources. If approved, this will become the official recommended methodology for determining the costs of PU treatment, thereby creating conditions for homogenization and cost calculation in various contexts. This could provide information that serves as a basis for refining both insurance payments and the effective and increased allocation of funds for PU prevention.

4.1 | Strengths and limitations of the research

A potential limitation of this study is that it was conducted in a single inpatient healthcare facility, which may affect the generalizability of the findings to other

healthcare settings. However, as the goal of the study was to develop and validate a comprehensive cost-of-illness model and methodology for the cost analysis of PU treatment, the sample size and controlled setting could be considered a strength rather than a limitation.

This setting provided an opportunity to rigorously validate our methodology and accurately determine the proper documentation procedures. The data collection was ensured through rigorous training of data managers and continuous checks of the validity of records. Additionally, a significant strength of our research lies in its comprehensive analysis, which includes not only the direct costs of materials but also the time dedicated to care and the necessary procedures for PU management, all based on real-world clinical cost data.

4.2 | Theoretical contribution

This study significantly advances the theoretical understanding of PU management costs. Developing a detailed and robust cost model using a bottom-up, person-based approach provides a comprehensive framework for future economic evaluations in healthcare. The integration of real-world clinical data enhances the model's reliability and applicability, ensuring it accurately reflects clinical practices and resource utilization.

Moreover, the study contributes to the standardization of cost analysis methodologies. The national methodology for PU cost analysis proposed here promotes uniformity and comparability across different healthcare settings, aiding in the consistent understanding of PU-related costs. Additionally, the identification of key cost drivers, such as patient demographics and clinical settings, offers valuable insights into the economic dynamics of PU treatment, laying a theoretical foundation for targeted research and interventions.

4.3 | Implications for clinical practice

The findings of this study have significant implications for clinical practice, particularly in the management and prevention of PUs. The detailed cost analysis provides

TABLE 6 Future research directions.

Research area	Description
Validation of Cost Model Across Different Settings	Validate the cost model in diverse healthcare settings beyond the selected university hospital. This includes testing the model in other hospitals, including those in rural or less-resourced areas, to ensure its generalizability and applicability in varying clinical environments.
Longitudinal Studies on Cost Trends	Conduct longitudinal studies to understand the trends in the costs associated with PU treatment over time. This approach will also provide insights into the long-term economic impact of PUs and the effectiveness of interventions aimed at reducing these costs.
Impact of Prevention Strategies on Cost Reduction	Research should be directed towards assessing the cost-effectiveness of various PU prevention strategies. By comparing the costs associated with preventive measures versus treatment costs, healthcare providers can develop more effective resource allocation strategies.
Detailed Analysis of Cost Drivers	Future research should delve deeper into the specific factors driving costs, such as the type of treatment materials used, the intensity of care, and patient-specific variables like comorbid conditions. Understanding these drivers will enable more targeted interventions to reduce unnecessary expenses.
Incorporation of Quality of Life Metrics	Including patient-reported outcomes and quality of life metrics in future studies will provide a more holistic view of the impact of PUs. This can help correlate financial costs with the broader implications for patient well-being and satisfaction.
Comparative Studies Across Countries	Comparative research involving multiple countries will be valuable in understanding how different healthcare systems and policies influence the costs associated with PU treatment. Such studies can identify best practices and policy recommendations that could be implemented globally.
Technological Innovations in PU Management	Investigating the role of technological innovations, such as advanced wound care products and digital health tools, in reducing the costs and improving the outcomes of PU treatment is a promising area for future research. This includes cost–benefit analyses of new technologies and their integration into standard care practices.
Policy and Insurance Implications	Future research should explore the implications of the study's findings for healthcare policy and insurance reimbursement practices. This includes evaluating how standardized cost calculation methodologies can influence insurance payments and resource allocation within healthcare systems.

healthcare administrators and policymakers with essential data to make informed decisions regarding budget allocations and resource management. By understanding specific cost drivers, hospitals can prioritize interventions, potentially reducing overall costs.

The development of a national methodology for cost analysis promotes standardization in cost calculations across healthcare settings, enhancing the accuracy of insurance reimbursements and ensuring adequate compensation for hospitals based on the case mix of patients. Identifying high-cost patient demographics and clinical settings enables targeted preventive measures, improving patient outcomes and lowering treatment costs.

The insights gained can inform policy development, emphasizing cost-effective PU management and prevention strategies, ultimately improving patient care and reducing healthcare expenditures with consistent support for effective preventive measures.

4.4 | Future research

While this study significantly contributes to our understanding of the costs associated with PU treatment, it also highlights the vast scope for further research. The findings underscore the complexity of managing PUs in inpatient healthcare settings and the need for more comprehensive and nuanced studies. Despite the progress made, much work remains to be done to fully understand and address the economic, clinical, and policy-related aspects of PU management. Table 6 outlines key areas where further investigation is needed to enhance patient outcomes, optimize resource allocation, and improve healthcare policies.

The authors plan to address some of the above mentioned research directions through a future multicentric study, which will aim to validate findings across different healthcare settings and explore the outlined areas in greater depth.

5 | CONCLUSION

This study comprehensively analysed the costs associated with treating PUs in hospitalized patients in the Czech Republic, using detailed data from the university hospital. By employing a rigorous methodology, the research accurately quantified the significant financial burden of PU treatment, particularly the costs associated with materials, labour, and pharmacotherapy. The resulting cost model provides a valuable tool for understanding and managing these expenses across different hospital departments.

The study's findings have led to the development of a national methodology for cost analysis of PU treatment. This standardization will enhance the accuracy of cost calculations, improve insurance reimbursements, and optimize resource allocation.

Overall, this research advances the understanding of PU treatment costs, offering crucial insights for clinical practice and future research. By supporting the development of targeted interventions, the study aims to improve patient outcomes and reduce healthcare costs related to PUs.

ACKNOWLEDGEMENTS

The authors have nothing to report.

FUNDING INFORMATION

This work was supported by the Ministry of Health of the Czech Republic under grant no. NU20-09-00094. 'Cost analysis of pressure ulcers treatment—determinant of care'. All rights reserved.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Majority of data are presented. The data that further support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The whole project was approved by the Ethical Committee of the University Hospital Ostrava and Masaryk University, Faculty of Medicine. No specific number was given for the approval.

ORCID

Andrea Pokorná https://orcid.org/0000-0002-1305-6455

REFERENCES

1. EPUAP, NPIAP, PPPIA. In: Haesler E, ed. *Prevention and Treatment of Pressure Ulcers/Injuries: Clinical Practice Guideline*. European Pressure Ulcer Advisory Panel; 2019:404.
2. Bůřilová P, Pokorná A, Benešová K, et al. A ten-year follow-up of the prevalence of pressure injuries in The Czech Republic: analysis of the national registry. *Int Wound J*. 2022;19:1870-1877.
3. Pokorná A, Dolanová D, Benešová K, et al. How the COVID-19 pandemic influences the prevalence of pressure injuries in The Czech Republic: a nationwide analysis of a health registry in 2020. *J Tissue Viability*. 2022;31(3):424-430.
4. Krupová L, Pokorná A. Quality of life in patients with non-healing wounds, with particular focus on assesment tools – a literature review. *Cent Eur J Nurs Midwifery*. 2020;11(2):94-103.
5. Solmos S, LaFond C, Pohlman AS, Sala J, Mayampurath A. Characteristics of critically ill adults with sacrococcygeal

unavoidable hospital-acquired pressure injuries: a retrospective, matched, case-control study. *J Wound Ostomy Continence Nurs*. 2021;48(1):11-19.
6. Brem H, Maggi J, Nierman D, et al. High cost of stage IV pressure ulcers. *Am J Surg*. 2010;200(4):473-477.
7. Krupová L, Krupa M, Benešová K, et al. Sledování prevalence dekubitů—srovnání národních dat s daty konkrétního poskytovatele zdravotních služeb—Fakultní nemocnice Ostrava. *Čes Slov Neurol Neurochir*. 2022;85/118(Suppl 1):21-27.
8. Smith S, Snyder A, McMahon LF, Petersen L, Meddings J. Success in hospital-acquired pressure ulcer prevention: a tale in two data sets. *Health Aff*. 2018;37(11):1787-1796.
9. Demarré L, Van Lancker A, Van Hecke A, et al. The cost of prevention and treatment of pressure ulcers: a systematic review. *Int J Nurs Stud*. 2015;52(11):1754-1774.
10. Pokorná A, Krupová L, Benešová K, et al. Challenges in prospective observational studies evaluating pressure ulcer costs: how to price the items correctly. *J Wound Care*. 2023;32(9):579-586.
11. Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) statement: updated reporting guidance for health economic evaluations. *BMJ*. 2022;11:e067975.
12. Kottner J, Cuddigan J, Carville K, et al. Pressure ulcer/injury classification today: an international perspective. *J Tissue Viability*. 2020;29(3):197-203.
13. Klugarová J, Pokorná A, Hussain S, et al. Economic evaluations of interventions for the prevention and treatment of pressure ulcers: an umbrella review protocol. *JBI Evid Synth*. 2022;20(2):633-639.
14. Padula WV, Mishra MK, Makic MBF, Sullivan PW. Improving the quality of pressure ulcer care with prevention: a cost-effectiveness analysis. *Med Care*. 2011;49(4):385-392.
15. Dealey C, Posnett J, Walker A. The cost of pressure ulcers in the United Kingdom. *J Wound Care*. 2012;21(6):261-266.
16. Ocampo W, Cheung A, Baylis B, et al. Economic evaluations of strategies to prevent hospital-acquired pressure injuries. *Adv Skin Wound Care*. 2017;30(7):319-333.
17. Palfreyman SJ, Stone PW. A systematic review of economic evaluations assessing interventions aimed at preventing or treating pressure ulcers. *Int J Nurs Stud*. 2015;52(3):769-788.
18. Mohamed TH. Risk factors of pressure ulcers in hospitalized elderly Egyptian people. *Egypt J Geriatr Gerontol*. 2021;8(2):1-7.
19. Tsai YJ, Lin CH, Yen YH, et al. Risk factors for pressure ulcer recurrence following surgical reconstruction: a cross-sectional retrospective analysis. *Front Surg*. 2023;3(10):970681.
20. Cooper KL. Evidence-based prevention of pressure ulcers in the intensive care unit. *Crit Care Nurse*. 2013;33(6):57-66.
21. Hansen Edwards C, Håkon Bjørngaard J, Minet Kinge J, et al. The healthcare costs of increased body mass index–evidence from The Trøndelag Health Study. *Health Econ Rev*. 2024;14(1):36.
22. Lichterfeld-Kottner A, Lahmann N, Kottner J. Sex-specific differences in prevention and treatment of institutional-acquired pressure ulcers in hospitals and nursing homes. *J Tissue Viability*. 2020;29(3):204-210.

How to cite this article: Krupová L, Pokorná A, Krupa M, Benešová K. Comprehensive cost-of-illness analysis of pressure ulcer treatment: A real-world study at a Czech university hospital. *Int Wound J*. 2025;22(1):e70137. doi:10.1111/iwj.70137